been set up at Rothamsted and elsewhere, and we are hoping to achieve good results; much valuable information has already been obtained.

(3) We are also looking to the tractor to achieve great things on the farm. It will allow considerable development of cultivation implements, enable us to improve our tillage and to keep down weeds, a very serious trouble in the southern part of England. Good Scottish farmers in that region have told me that farming in Scotland is much easier than in England, because the rigorous northern winters keep weeds in check, while the mild southern winters encourage their growth.

(4) It is possible that certain substances, such as boric acid, the fluorides, etc., studied by Gautier and Claussmann in France, may help in raising crop growth.

(5) It is possible also that special methods may prove of value, such as the high-tension discharge tested by Miss Dudgeon at Lincluden, Dumfries, and ably and critically studied by Prof. V. H. Blackman.

(6) Finally, it seems probable that some wholly new method may be found for increasing crop growth. In most civilised countries there are now research institutes where the ways of plants and the properties of soils are being studied. Men of science, as a rule, do not care to risk prophecies or to attempt to create sensations, and I certainly am not going to break this wholesome rule. Something, however, has already been done; in spite of the decreased labour spent on cultivation, the yields tend to go up, while the new knowledge that is now being gained is adding greatly to the pleasure of farming and giving both masters and men an interest in their work that they never had before.

## Applied Geography.[1]

By D. G. Hogarth, M.A., D.Litt., C.M.G.

The term "applied geography" has been in use for some years as a general designation of lendings or borrowings of geographical results, whether by a geographer who applies the material of his own science to another, or by a geologist or a meteorologist, or again an ethnologist or historian, who borrows of the geographer. Whether geography makes the loan of her own motion or not, the interest in view, as it seems to me, is primarily that, not of geography, but of another science or study.

Such applications are of the highest interest and value as studies, and, still more, as means of education. As studies, not merely are they links between sciences, but they tend to become new subjects of research, and to develop with time into independent sciences. As means of education they are used more generally, and prove themselves of higher potency than the pure sciences from which or to which, respectively, the loans are effected. But, in my view, geography, thus applied, passes, in the process of application, into a foreign province and under another control. It is most proper, as well as most profitable, for a geographer to work in that foreign field; but, while he stays in it, he is, in military parlance, seconded.

Logical as this view appears to me, and often as, in fact, it has been stated or implied by others (for example, by one at least of my predecessors in this chair, Sir Charles Close, who delivered his presidential address to the section at the Portsmouth meeting in 1911), it does not square with some conceptions of geography put forward by high authorities of recent years. These represent differently the status of some of the studies, into which, as I maintain, geography enters as a secondary element. In particular, there is a school, represented in this country and more strongly in America, which claims for geography what, in my view, is an historical or ethnological or even psychological study, using geographical data towards the solution of problems in its own field; and some even consider this not merely a function of true geography, but its principal function now and for the future. Their "new geography" is and is to be the study of "human response to land-forms." This is an extreme American statement; but the same idea is instinct in such utterances, more sober and guarded, as that of a great geographer, Dr. H. R. Mill, to the effect that the *ultimate* problem of geography is "the demonstrative and quantitative proof of the control exercised by the earth's crust on the mental processes of its inhabitants." Dr. Mill is too profound a man of science not to guard himself, by that saving word "ultimate," from such retorts as Prof. Ellsworth Huntington, of Yale, has offered to the extreme American statement. If, the latter argued, geography is actually the study of the human response to land-forms, then, as a science, it is in its infancy, or, rather, it has returned to a second childhood; for it has scarcely begun to collect exact data to this particular end, or to treat them statistically, or to apply to them the methods of isolation that exact science demands. In this country geographers are less inclined to interpret "new geography" on such revolutionary lines; but one suspects a tendency towards the American view in both their principles and their practice—in their choice of lines of inquiry or research and their choice of subjects for education. The concentration on man, which characterises geographical teaching in the University of London, and the almost exclusive attention paid to economic geography in the geographical curricula of some other British universities tend in that direction.

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[1] Abridged from the presidential address delivered to Section E (Geography) of the British Association at Edinburgh on September 8.

In educational practice this bias does good, rather than harm, if the geographer bears in mind that geography proper has only one function to perform in regard to man—namely, to investigate, account for, and state his distribution over terrestrial space—and that this function cannot be performed to any good purpose except upon a basis of physical geography—that is, on knowledge of the disposition and relation of the earth's physical features so far as ascertained to date. To deal with the effect of man's distribution on his mental processes or political and economic action is to deal with him geographically, indeed, but by applications of geography to psychology, to history, to sociology, to ethnology, and to economics, for the ends of these sciences; though the interests of geography may be, and often are, well served in the process by reflection of light on its own problems of distribution. If in instruction, as distinct from research, the geographer, realising that, when he introduces these subjects to his pupils, he will be teaching them not geography, but another science with the help of geography, insists on their having been grounded previously or elsewhere in what he is to apply—namely, the facts of physical distribution—all will be well. The application will be a sound step forward in education, more potent perhaps for training general intelligence than the teaching of pure geography at the earlier stage, because making a wider and more compelling appeal to imaginative interest and pointing the adolescent mind to a more complicated field of thought. But if geography is applied to instruction in other sciences without the recipients having learned what it is in itself, then all will be wrong. The teacher will talk a language not understood, and the value of what he is applying cannot be appreciated by the pupils.

It will be patent enough by now that I am maintaining geography proper to be the study of the spatial distribution of all features on the surface of the earth. My view is, of course, neither novel nor rare. Almost all who of late years have discussed the scope of geography have agreed that distribution is of its essence. Among the most recent exponents of that view have been two directors of the Oxford school, Sir Halford Mackinder and Prof. Herbertson. When, however, I add that the study of distribution, rightly understood, is the whole essential function of geography, I part company with the theory of some of my predecessors and contemporaries, and the practice of more. But our divergence will be found to be not serious; for not only do I mean a great deal by the study of distribution—quite enough for the function of any one science!—but also I claim for geography to the exclusion of any other science all study of spatial distribution on the earth's surface. This study has been its well recognised function ever since a science of that name has come to be restricted to the features of the terrestrial surface—that is, ever since "geography" in the eighteenth century had to abandon to its child geology the study of what lies below that surface even as earlier it had abandoned the study of the firmament to an elder child, astronomy. Though geography has borne other children since, who have grown to independent scientific life, none of these has robbed her of that one immemorial function. On the contrary, they call upon her to exercise it still on their behalf.

Let no one suppose that I mean by this study and this function merely what Prof. Herbertson so indignantly repudiated for an adequate content of his science—physiography *plus* descriptive topography. Geography includes these things, of course, but she embraces also all investigation both of the actual distribution of the earth's superficial features and of the causes of the distribution, the last a profound and intricate subject towards the solution of which she has to summon assistance from many other sciences and studies. She includes, further, in her field, for the accurate statement of actual distribution, all the processes of survey—a highly specialised function to the due performance of which other sciences again lend indispensable aid; and, also, for the diagrammatic presentation of synthetised results for practical use, the equally highly specialised processes of cartography. That seems to me an ample field, with more than sufficient variety of expert functions, for any one science.

I have claimed for the geographer's proper field the study of the causation of distribution. I am aware that this claim has been, and is, denied to geography by some students of the sciences which he necessarily calls to his help. But if a science is to be denied access to the fields of other sciences unless it take service under them, what science shall be saved? I admit, however, that some disputes can scarcely be avoided, where respective boundaries are not yet well delimited. Better delimitation is called for in the interest of geography, because lack of definition, causing doubts and questions about her scope, confuses the distinction between the science and its application. The doubts are not really symptoms of anything wrong with geography, but, since they may suggest to the popular mind that in fact something is wrong, they can be causes of disease. Their constant genesis is to be found in the history of a science the scope of which has not always been the same, but has contracted during the course of ages in certain directions while expanding in others. If, in the third century B.C., Eratosthenes had been asked what he meant by geography, he would have replied, the science of all the physical environment of man whether above, upon, or below the surface of the earth, as well as of man himself as a physical entity. He would have claimed for its field what lies between the farthest star and the heart of our globe, and the nature and relation of everything composing the universe. Geography, in fact, was then not only the whole of natural science, as we understand the term, but also everything to which another term, ethnology, might now be stretched at its very widest.

Look forward now across two thousand years to the end of the eighteenth century A.D. Geography has long become a mother. She has conceived and borne astronomy, chemistry, botany, zoology, and many more children, of whom about the youngest is geology. They have all existences separate from hers and stand on their own feet, but they preserve a filial connection with her and depend still on their mother science for a certain common service, while taking off her hands other services she once performed. Restricting the scope of her activities, they have set her free to develop new ones. In doing this she will conceive again and again and bear yet other children during the century to follow—meteorology, climatology, oceanography, ethnology, anthropology, and more. Again, and still more narrowly, this new brood will limit the mother's scope; but ever and ever fecund, she will find fresh activities in the vast field of earth knowledge, and once and again conceive anew. The latest child that she has borne and seen stand erect is geodesy; and she has not done with conceiving.

Ever losing sections of her original field and functions, ever adding new sections to them, geography can scarcely help suggesting doubts to others and even to herself. There must always be a certain indefiniteness about a field on the edges of which fresh specialisms are for ever developing towards a point at which they will break away to grow alone into new sciences. The mother holds on awhile to the child, sharing its activities, loth to let go, perhaps even a little jealous of its growing independence. It has not been easy to say at any given moment where geography's functions have ended and those of, say, geology or ethnology have begun. Moreover, it is inevitably asked about this fissiparous science from which function after function has detached itself to lead a life apart—what, if the process continues, as it shows every sign of doing, will be left to geography? Will it not be split up among divers specialisms, and become in time a venerable memory? It is a natural, perhaps a necessary, question. But what is wholly unnecessary is that any answer should be returned which implies a doubt that geography has a field of research and study essentially hers yesterday, to-day, and to-morrow; still less one which implies any suspicion that, because of her constant parturition of specialisms geography is, or is likely to be in any future that can be foreseen, moribund.

Since geography, as I understand it, is a necessary factor in the study of all sciences, and must be applied to all if their students are to apprehend rightly the distribution of their own material, it is a necessary element in all education. Unless, on one hand, its proper study be supported by such means as the State, the universities, and the great scientific societies control, and, on the other, its application to the instruction of youth be encouraged by the same bodies, the general scientific standard in these islands will suffer; our system of education will lack an instrument of the highest utility for both the inculcation of indispensable knowledge and the training of adolescent intelligence; and a vicious circle will be set up, trained teachers being lacking in quantity and quality adequate to train pupils to a high enough standard to produce out of their number sufficient trained teachers to carry on the torch.

The present policy of the English Board of Education, as expressed in its practice, encourages a four-years' break in the geographical training of the young, the break occurring between the ages of fourteen and eighteen, the best years of adolescent receptivity. If students are to be strangers to specifically geographical instruction during all that period any geographical bent given to their minds before the age of fourteen is more than likely to have disappeared by the time they come to eighteen years. The habit of thinking geographically—that is, of considering group distribution—cannot have been formed; and the students, not having learned the real nature of the science applied, will not possess the groundwork necessary for the apprehension of the higher applications of geography. Moreover, as Sir Halford Mackinder has rightly argued, an inevitable consequence of this policy is that the chief prizes and awards offered at the end of school-time are not to be gained by proficiency in geography. Therefore, few students are likely to enter the university with direct encouragement to resume a subject dropped long before at the end of the primary period of their education.

It is not, of course, the business of schools, primary and secondary, to train specialists. Therefore one does not ask that pure geographical science should have more than a small share of the compulsory curriculum—only that it have some share. If this is assured, then its applications, which on account of their highly educative influence deserve an equally compulsory but larger place in the curriculum, can be used to full advantage. The meaning and value of the geographical ingredient in mixed studies will stand a good chance of being understood, and of exciting the lively interest of young students. In any case, only so will the universities be likely to receive year by year students sufficiently grounded to make good use of higher geographical courses, and well enough disposed to geography to pursue it as a higher study and become in their turn competent teachers.

The obligation upon the universities is the same in kind, but qualitatively greater. They have to provide not only the highest teaching, both in the pure science and its applications, but also such encouragements as will induce students of capacity to devote their period of residence to this subject. The first part of this obligatory provision has been recognised and met in varying degrees by nearly all British universities during the past quarter of a century. A valuable report compiled recently by that veteran champion, Sir John Keltie, shows that, in regard to geography, endowment of professorial chairs, allocations of stipends to readers, lecturers, and tutors, supply of apparatus for research and instruction and organisation of "honours" examinations, have made remarkable progress in our university world as a whole. But no British university has yet provided all that is requisite or desired. Oxford and Cambridge, which have well-equipped geographical laboratories, still lack professorial chairs. Liverpool, maintaining a well-staffed department of geography, and London, which, between University College and the School of Economics, provides all the staff and apparatus required for teaching, have endowed chairs; but they direct the attention of the holders to applications of geography rather than to the pure science. So also do the University of Manchester and the University College of Wales, both of which maintain professors of geography.

All the universities, with but one or two exceptions, examine in the subject to a high standard, that set by Cambridge being perhaps the highest over the whole field of properly geographical study. This latter university, also, has met the second part of her obligation to geography by the organisation of an honours course of instruction and classified examination, which, if pursued throughout a student's residence, is sufficient in itself to secure graduation. At Cambridge, therefore, geography may be said to stand on a par with any other self-contained final subject. Neither in London nor in Manchester (I am not quite sure about Liverpool, but believe its case to be the same) is geography, in and by itself, all-sufficient yet to secure graduation, though at London the supplementary subject is so far subordinated to geography that the degree is taken as in the latter subject. Oxford offers distinctly less encouragement at present than any of the universities just mentioned. Her teaching and her examination standard are as advanced as the best of theirs, and the highest award which she gives for proficiency in geography, her diploma "with distinction," counts towards the B.A. degree as two-thirds of the whole qualification; but—and here's the rub!—the balance has to be made up by proficiency in some other subject up to a pass, not an honours, standard. Therefore the resultant degree does not stand before the world as one taken in honours; and, although some candidates are notified as distinguished and some not in the geographical part of her examinations, the distinction is not advertised in the form to which the public is accustomed—namely, an honours list divided into classes. The net result is that an Oxford diploma, however brilliantly won, commands less recognition in the labour market than would a class in an honours school or tripos. It should, however, be mentioned—though an infrequent occurrence, not advertised by a class list, makes little impression on public opinion—that special geographical research, embodied in a thesis, can qualify at Oxford for higher degrees than the B.A.—viz. for the B.Litt. and B.Sc.—without the support of other subjects.

The reason of this equivocal status of geography at Oxford is simply that, so far as the actual faculties which control the courses for ordinary graduation are concerned, geography is, in fact, an equivocal subject. No one faculty feels that it can deal with the whole of it. The arts faculties will not accept responsibility for the elements of natural and mathematical science which enter into its study and teaching—for example, into the investigation of the causes of distribution, into the processes of surveying, into cartography, and into many other of its functions. Moreover, the traditional Oxford requirement of a literary basis for arts studies is hard, if not impossible, to satisfy in geography. The faculty of natural science, on the other hand, is equally loth to be responsible for a subject which admits so much of the arts element, especially into those applications of its data which enter most often into the instructional curriculum of adolescents—for example, its applications to history and to ethnology.

At this moment, then, there is an *impasse* at Oxford similar to that (it is caused by the same reason) which prevents the election of a geographer, as such, either to the Royal Society on the one hand, or to the British Academy on the other. But ways out can be found if there be good will towards geography, and such general recognition of the necessity of bringing it into closer relation with the established studies as was implied by the examiners in the Oxford school of Literae Humaniores last year, when, in an official notice, they expressed their sense of a lack of it in the historical work with which they had to deal. Faculties are comparatively modern organisations at Oxford as at Cambridge for the control of teaching and examining. Before them existed boards of studies, appropriated to narrower subjects; and, indeed, such boards have been constituted since faculties became the rule and side by side with them. The board, which at first controlled at Oxford the final honours school of English, is an example and a valid precedent. Cambridge has found it possible to organise a mixed board of studies to manage a final school of geography, the board being composed of representatives of both the arts subjects and the natural and mathematical sciences; and this acts apparently to the general satisfaction even in the absence of a professor of the special subject for the teaching and testing of which it was formed. Why, then, should Oxford not do likewise? If Cambridge has not waited for the endowment of a professorial chair in geography, need Oxford wait? I am well aware that, when at the latter university the school of English came into existence, there were already two chairs appropriated to its subject; and I grant that Oxford will not have the very best of all guarantees that a high standard will be maintained in the instructional courses and the examinations in geography until there is a professor *ad hoc*. But guarantees sufficient for all practical purposes she could obtain to-morrow by composing a board out of her existing teachers of geography and kindred sciences.

For the last time, then, let me rehearse the too familiar "vicious circle." The supply of good students depends on a supply of good teachers; the supply of good teachers depends on a supply of good students. If either supply fails, it is not geography alone, but all sciences and studies, that will be damnified; for all require the best of the help she can give in proportion as her science grows and improves. History will be able to call but indifferent geography to her assistance if this science has been understaffed and discouraged by official reluctance to allow it a place of its own in the sun. Is there not still some such reluctance on the part of the Board of Education, of some of our universities, and of the Civil Service Commissioners?

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## Stellar Parallax.

By J. JACKSON, Chief Assistant, Royal Observatory, Greenwich.

THE determination of stellar distances is fundamental to the investigation of the sidereal universe. When once the distance of a star is known, we can calculate its transverse speed in kilometres a second from its proper motion in seconds of arc per century, and we can determine its absolute brightness from its apparent brightness. For binary stars at known distances we can determine the separation of the components in kilometres, and this, together with the period, enables us to compute the mass of the system. Recent work at Mount Wilson has shown that it is practicable to determine the angular diameter of the larger stars, and for such stars a knowledge of the parallax will enable us to compute the linear diameter. Many of the investigations about the sidereal universe made during the last twenty years have been possible only through the increase in the number of stars the distances of which are known with reasonable accuracy, and the results obtained have been of such importance that in an increasing degree the energy of astronomers is being directed to supply the required data.

The direct determination of stellar distances depends on triangulation from the earth at different positions in its annual path round the sun. The apparent motion of a star can be analysed into a linear component due to the relative motion of the sun and the star, and a periodic motion due to the motion of the earth round the sun. The parallax of a star is the angle subtended by the earth's radius at the distance of the star, and is equal to the semi-major axis of the apparent ellipse described by the star as a result of the earth's orbital motion. It is therefore determined from observations made as nearly as practicable at the times when the star is at the ends of the major axis of the "parallactic ellipse."

The principle to be used in the determination of stellar distances was obvious as soon as the Copernican theory of the solar system was recognised. The difficulty in applying the principle is due to the extreme minuteness of the change in angle which is to be measured after a six months' interval. Had it been known or assumed that the stars were comparable in real brightness with our sun, although they appeared about a million million times fainter, it could have been calculated that their parallaxes were less than a second of arc. Successive attempts to measure the parallaxes of selected stars for long necessarily met with failure, although they led to many important discoveries. In the first half of the eighteenth century Bradley made a remarkable series of observations of the meridian zenith distance of the star $\gamma$ Draconis—a star which passed the meridian near the zenith so that the angles to be measured were relatively small, while errors introduced by varying atmospheric conditions were reduced to a minimum. He discovered aberration and later nutation through these observations, and proved that the parallax of this star was less than a second. Observations of the same kind might later have led to the discovery of latitude variation. The attempt made by Sir William Herschel towards the end of the eighteenth century may also be noted here. Instead of attempting to determine the absolute parallax of separate stars which involves the measurement of large angles from the vertical or some other direction which it is supposed can be accurately identified after a six months' interval, he attempted only to discover relative parallaxes from the relative displacements of stars in nearly the same direction, but probably at very different distances. The method is essentially that now used almost exclusively; but where Herschel applied it to pairs of stars actually at different distances, his observations were not sufficiently accurate to reveal the parallactic motion. His most extensive series of observations were made of fairly bright pairs of stars within a few seconds of arc, and the motion he actually discovered was orbital motion of the stars, which proved that they were really close together in space and revolving round one another under gravitational attraction. This discovery led to the systematic study of double stars.

Success in the determination of stellar parallax was obtained almost simultaneously about 1838 by three observers employing different methods on different stars. The principal credit is usually given to Bessel for his determination of the parallax of 61 Cygni—a pair of faint stars with large proper motion—relative to faint neighbouring stars by means of the heliometer. This instrument consists of an ordinary telescope with the object glass cut in two along a diameter, and means are supplied for rotating the object glass and for sliding the two halves along their common diameter. With this instrument each star forms two images, and the observation consists in bringing an image of one star into coincidence with the other image of the other star. The